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Case Report

Lightning fatality with blast, flame, heat and current effects: A macroscopic and microscopic view

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ABSTRACT

A case is presented of a fatal environmental accidental injuries of lightning. A pedestrian was struck by lightning. The macroscopic and microscopic lightning injuries are reviewed.

1. Introduction

Lightning is defined as a momentary, atmospheric, transient, high current electrical discharge whose path length is measured in kilometers[1] from sky to earth. In tropical and subtropical countries accidental deaths from lightning are not uncommon. Malaysia has frequent rains with thundering and lightning. It is an important cause of weather-related morbidity and mortality in this part of the world. In lightning, very high voltages and amperages are involved and happen when highly charged thundercloud discharges via a huge arc to the ground.

Most lightning discharges are within clouds, while some cause electrical discharge from a cloud to earth. Most human deaths are caused by cloud-to-earth lightning strikes.[1] The current can spread over the surface of the body, pass through the body, or can take a pathway inside as in electricity passage through body. The body is completely paralyzed and person is unable to do much for his self-defence.

The thermal effects of the passage of the lightning current are related to intensity. Flashover burns over the skin are produced high intense current; blasting and disrupting are seen over clothing and inside the organs. When lightning is transmitted internally, it may produce sufficient heat and steam vapours to explode solid organs, fracture bones, or char areas of the organs. Focal haemorrhages from rupture of small vessels may be seen in the tissues. Interior part of the organs experience little less heat, coagulation but rupture vessels cause haemorrhages. In solid organs, it causes infarction and fragmentation of the tissues. Victims of lightning stroke show disruption of organ systems. The initial response of lightning stroke is paralysis of the vital centres, specifically respiratory centre, resulting apnoea; ventricular fibrillation or cardiac arrest.[2]Cardiac arrhythmias are very common with lightning stroke.[3]

Lightning patients exhibits any one or more out of four types of skin lesions: linear, punctuate, feathering, or thermal burns.[4–6] Feathering burns are not true burns because there are no damage to the skin.[7,8] They seem to be caused by electron showers induced by lightning that make a fern pattern on skin. Thermal burns occur if the clothing is ignited or may be caused by metal that the person is wearing or carrying during flashover.

Lightning injury can occur in five ways: direct strike, orifice entry, contact, side flash, and blunt trauma.[4] Experiments on sheep show that lightning strikes near the head may enter orifices such as ears, mouth, and eyes to flow internally.[8,9] Side flash or splash occurs as lightning jumps from its primary strike object to a nearby person on its way to ground.[10]

Blunt trauma from lightning can occur from two mechanisms; first, the person may be thrown to a considerable distance by the

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sudden, massive contraction caused by current passing through the body. Second, an explosive or implosive force occurs as the lightning pathway is instantaneously superheated and then rapidly cooled following the passage of the lightning.[4]

Tympanic membrane rupture is commonly found in lightning victims and may be due to the shock wave and air blast effect.[5,10,11] In fact, ruptured tympanic membranes are the most common blast injuries found in lightning victim. Severe optic injuries have also been reported in lightning injuries. Temporal bone pathology in such cases shows tympanic membrane rupture, mid ear haemorrhages, rupture of the Meissner membrane, and degenerative changes of the organ of Corti and of the facial nerve. Bilateral blindness associated with optic atrophy has also been found.[11–13]

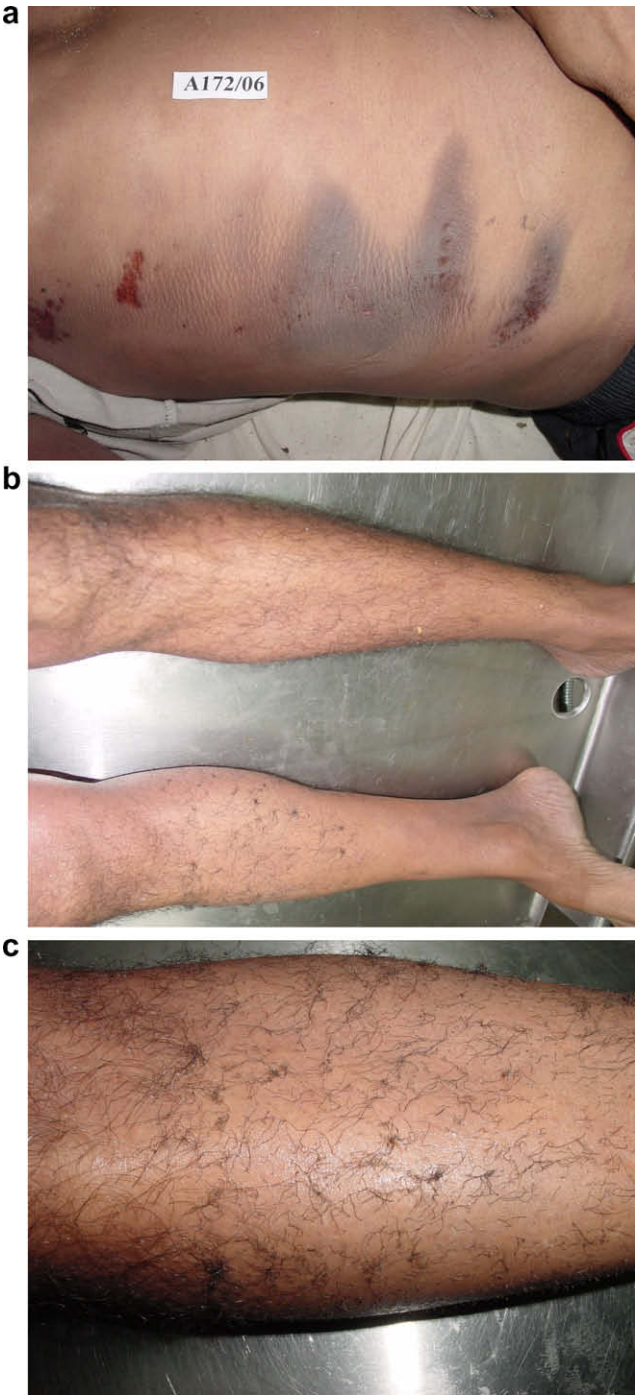
In lightning cases, all findings of burns, blast, and internal effect of heat are rarely shown through photographs in the literature earlier.

2. Case report

This is a case report of a labourer, who was going to his home after finishing his routine daily work in the evening hours around 7.30 pm in the month of April. There was heavy rain in Kuala Lumpur on this fateful day. There were tall trees on the side of road where he was walking. One lightning thunder struck in that area and hit him on right side of the body. He was brought dead to the casualty of PPUM Hospital, Kuala Lumpur.

Author conducted a complete post-mortem examination. The clothing, a cotton T-shirt and half pant of the victim were burnt, torn, and disarranged (Photograph 1b). There were superficial dermo-epidermal fire flash burns with burning and singeing of hair in chest and limb areas, mainly confining to the right side of the body (Photographs 1 and 2a–c); areas also showed blackening, base was having red angry look. The skin and underneath tissue in burnt areas were hardened. The head and face of the victim had reddened and swollen appearance with burns and singed hair (Photograph 3). There was bleeding from ears (Photograph 3), right eardrum was ruptured with blood collection in inside; left side eardrum was intact. All organs were congested. Brain was severely oedematous and showed congestion, there was a cerebral tonsil herniation, mushrooming effect in medulla oblongata (Photograph 4).The heart showed intense congestion and haemorrhages in septum following conduction pathway (Photograph 5). The lung surfaces showed diffuse haemorrhages, large size haemorrhages were present in basal, inter-lobar fissures and surface areas (Photograph 6); consistent with blast like lesions of contusions, disruption and damage to its structure. The intestines were haemorrhagic, slightly dilated, showing prominent parallel line tiger-skin like due to intense congestion appearance of inside rouge; appearing like paralytic bowel (Photograph 7). Liver surface was hardened and substance underneath was coagulated and congested. Spleen surface was also coagulated and hardened, underneath substance showed intense congestion. Histology of the organs [Photographs 8–16] showed intense heat and current effects. Most of the organs showed coagulation necrosis, haemorrhages, swelling and

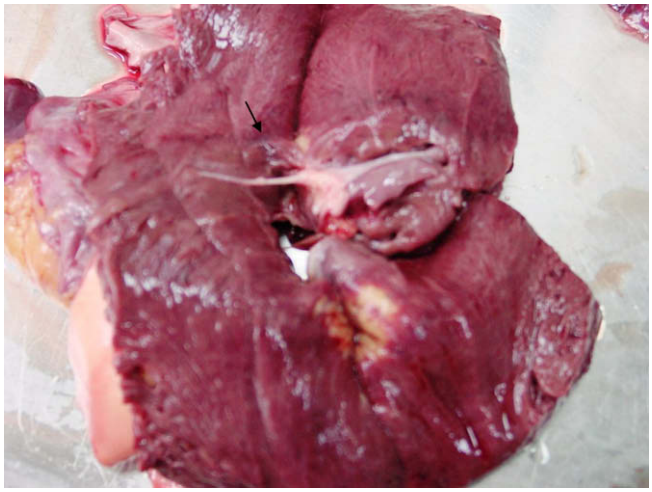
Photograph 1. Picture show torn, burnt, ripped and disarranged clothing of the victim.



Photograph 2. 2(a) Side flash burn of lightning arc on right side, trunk area; (b) Side flash burns with singeing of hair on right side, left lower limb otherwise almost intact; (c) Close-up view of singed hair on leg.

Photograph 3. Blast effect of lightning–bleeding through the right ear due to tympanic membrane ruptured. Head hair were burnt and singed. Face had superficial burns and was swollen; areas were reddened.

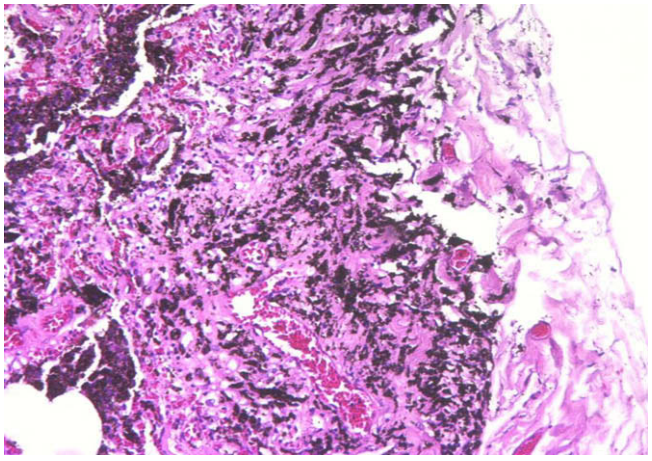
Photograph 4. Oedematous brain due to lightning, with mushroom like appearance of medulla oblongata, uncal grooving, projected tonsils by effect of lightning current passage.



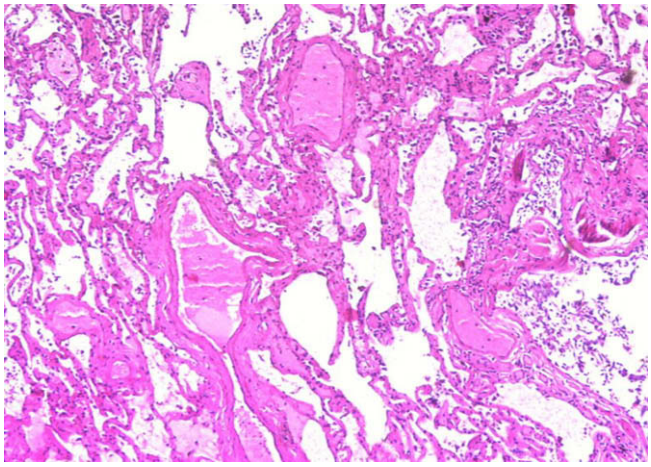
Photograph 5. Haemorrhagic areas along the of conduction pathway in septum area of the heart.

Photograph 6. Large size haemorrhages due to blast effect of lightning in interlobar fissure of right lung.

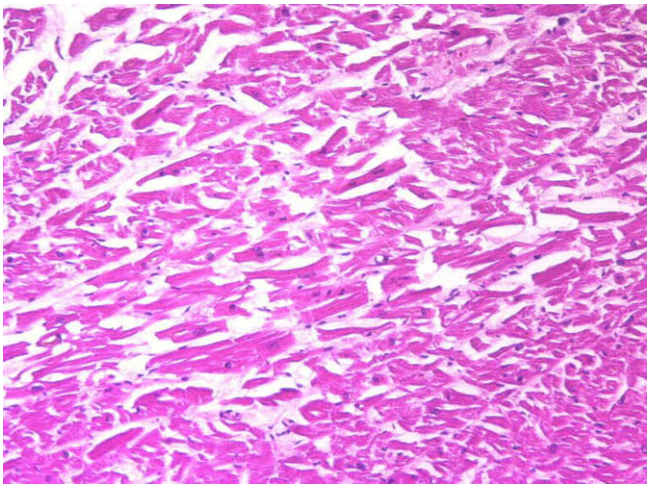
Photograph 7. Intestine with dilation and parallel line appearance of (Tiger skin like appearance) congested probably due to generalized paresis of nerve endings due to blast effect.



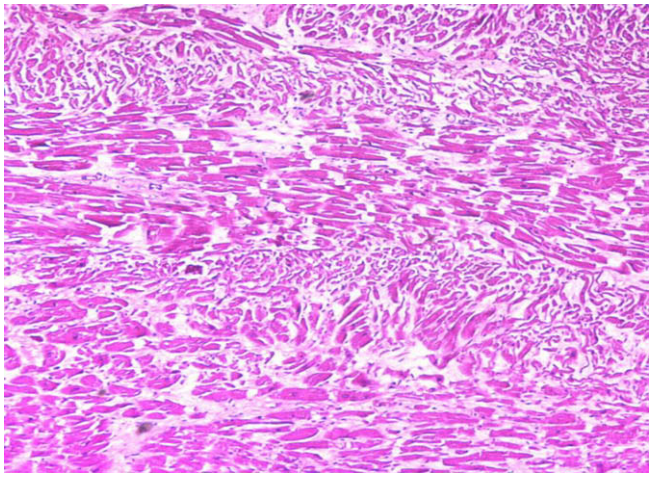
Photograph 8. Microphotograph of lung injuries by lightning showing haemorrhagic areas in lung with oedema, fragmentation, obvious gapping and necrosis [H&EX10].



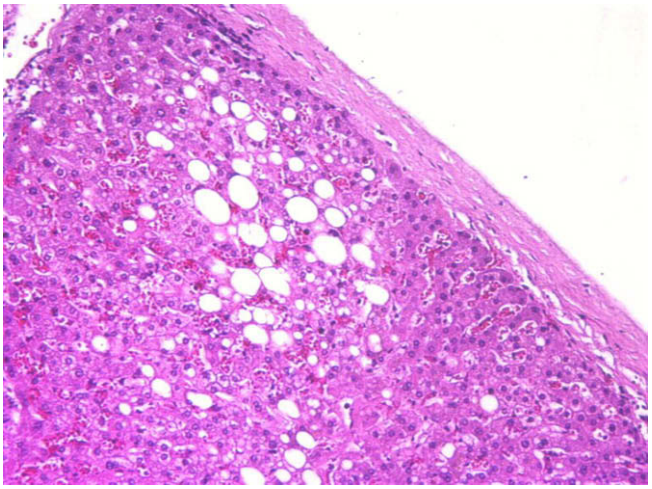
Photograph 9. Deeper part of lung showed pulmonary oedema and disruption of alveoli [H&EX40].



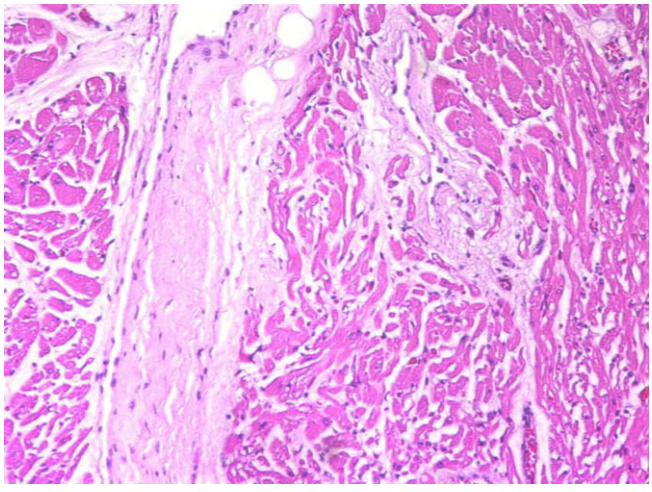
Photograph 12. Myocardium of heart showing effect of lightning, the fibres of muscles are necrosed, fragmented, separated and disrupted [H&EX40].



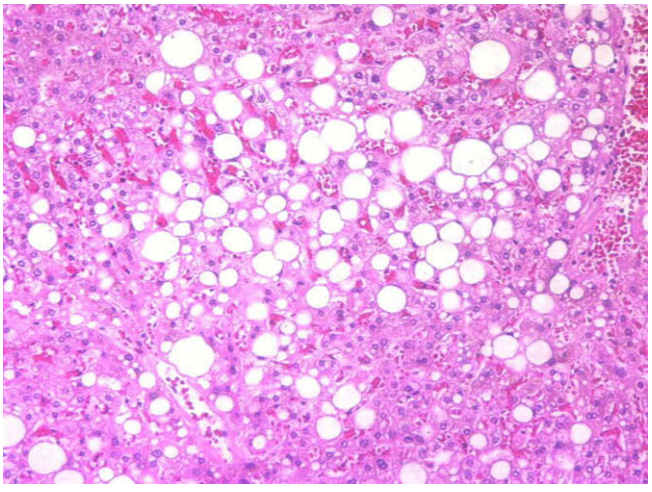
Photograph 10. Microphotograph of heart muscles showing necrosis, fragmentation and obvious disruption [H&EX40].



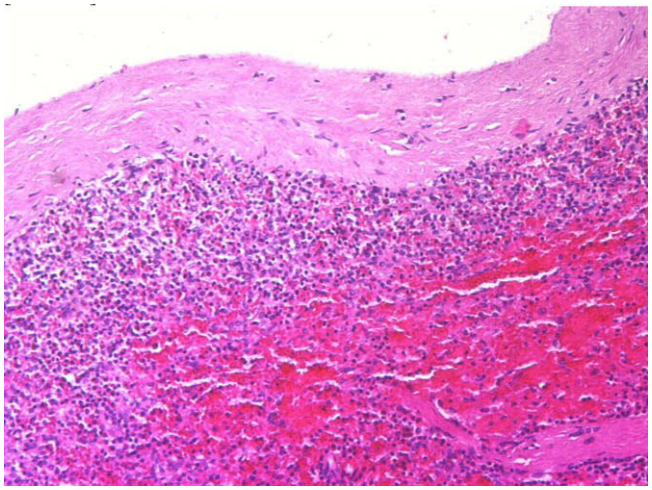
Photograph 13. Liver surface showed necrosis and 'streaming' of nuclei in surface area. Liver parenchyma cells showed vacuolization, disruption and pushing of nuclei [H&EX10].



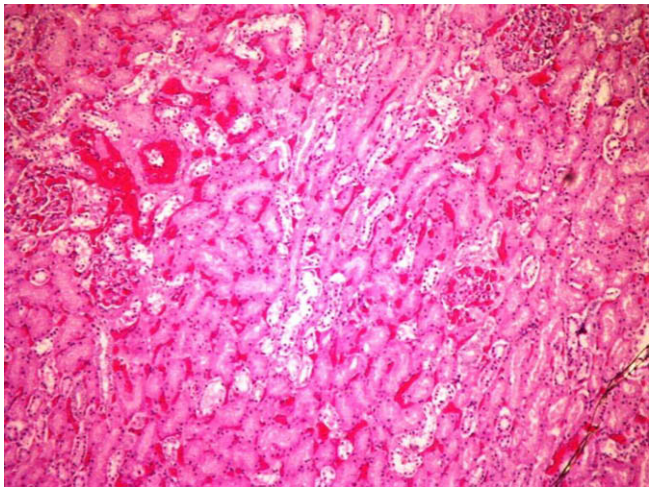
Photograph 11. Microphotograph of heart showing the effect of passage of lightning current, disruption of muscle fibre with vacuolization visible in some areas [H&EX40].



Photograph 14. Photograph of liver showing lightning injury effect (Bubbling effect) of lightning with extensive honey -comb vacuolization and congestion of sinusoids [H&EX40].



Photograph 15. Spleen showing areas of congestion, haemorrhagic areas and necrosis [H&EX10].



Photograph 16. Lightning injuries in kidney showing congestion, haemorrhagic areas with tubular disruption, necrosis and interstial inflammation [H&EX40].

disruption of fibres (Photographs 8–16). This case is presented through photographs and brief description (Photographs 1–16).

3. Discussion

It was rainy day and the clothing of the victim was wet so conduction of electric passage was smooth. This victim had effects of current, heat, and blast effects. All findings are discussed organ wise.

Skin: The burns of high-voltage and lightning injuries are very similar to arc injuries and flash burns. Extensive flash burns injuries by high voltage currents, lightning, or electric arcs generating temperatures in excess of 3,000°C.[14] Microscopically, the lesion shows honeycomb vacuolization of the keratin layer, and the epidermis and occasionally sub epidermal bullae may be seen. At the edge of the lesion, the epidermal nuclei are distorted, fusiform, and hypochromic, creating a "streaming pattern". The skin layers show fuzziness, flattening, and streaming of the nuclei.[15–17]

Intense oedema of the skin develops at points of entry of current in those who survive, probably due to paralysis of local capillary and lymphatic vessels.[18] He showed marked swelling of ear, eyelids and showed signs of cerebral oedema. He had also sustained tympanic membrane rupture on right side and blood was coming through perforation. In these findings of flash burn over chest and abdomen and lower limb, contact wound in head neck area, heat effect in skin, liver, spleen and other organs were seen.

CNS: The neuropathological findings in lightning include focal petechial haemorrhages and chromatolysis of pyramidal cells, Purkinje's cells of cerebellum, and anterior horn cells. The striking pathological feature of peripheral nerves is localized ballooning of myelin sheaths. The neuropathologic features of lightning were described as focal petechial haemorrhages, large vascular tears in the cerebrum, and neuronal degeneration of pyramidal cells of the neocortex and Purkinje cells of the cerebellum in post-mortem specimens by Critchley.[16] At times, injuries to nervous system are not just transient but permanent damage can also be observed; similar was noted in patients with spinal injuries.[19] The mortality rate from lightning is 30%, and up to 70% of survivors sustain significant morbidity.[5] One person of 45 years survived lightning stroke, his magnetic resonance imaging (MRI) showed ischemia in both cerebellar hemispheres; and in parietal, temporal, and frontal lobes of cerebrum.[17]

In one earlier reported case [16] of a 27-year-old male who has taken shelter in a tent and was injured by lightning as it struck a tree about 1.5 m away. He had hypoxemic brain damage. Brain death was diagnosed on the fifth day after injury. The discrete external findings contrasted markedly with the severe thermal damage to the pectoral muscle and cardiac musculature found during the autopsy.

One athlete survived lightning accident because he was wearing helmet.[17] Recovery has been reported even after 4 h in one lightning episode,[18] but in this case, he was brought dead, as effect was extensive.

CVS: Either cardiac damage may be caused by the electrical shock or induced vascular spasm.[13] The high temperature evolved during passage of an electrical current through tissues may produce coagulation necrosis and occlusion of small blood vessels. Microscopic examination reveals that the most severely damaged vascular layer is the media, which shows disintegration of elastic fibers by passage of current. In affected areas, the muscle fibers showed a "teased" or "shredded" appearance and show a granular and vacuolar degeneration.[12]

The shredding is apparently due to the combined effects of the heat and the spastic muscular contraction induced by the electrical current. In earlier case, the histological cardiac findings indicated severe acute myocardial infarction affecting virtually all parts of the myocardium.[12] In another reported fatal case of a 13-year-old boy who suffered acute myocardial infarction secondary to an indirect lightning strike. Almost every organ system may be impaired as lightning passes through the human body preferring the pathways that the lowest resistance between the contact points.[16] Primary causes of death in lightning strike is cardiac arrest, which may be associated with primary ventricular fibrillation or asystole.[20–24]

Respiratory: Pulmonary contusion and haemorrhage are possible with lightning injury.[22] Lightning acts as an instantaneous, massive direct current shock, simultaneously depolarizing the entire myocardium.[17] High-voltage currents induce tetanic spasms of respiratory muscles or directly inhibit the respiratory brain centre. The direct injury is produced by the passage of current through the various tissues. The indirect mechanism of injury is related to the heat generated by current passing through and overcoming the electrical resistance of the body tissues. The amount of heat generated by the current is directly proportional to the voltage of the current and inversely proportional to the efficiency of the biologic resistance.[25,26] Pulmonary contusion and haemorrhage are reported with lightning injury.[22]

GIT: Perforations in lightning are due to blast effect, as in this case, there was tympanic membrane perforation and effect on lungs and intestine. In similar lightning case,[27] there were perforations of terminal ileum and descending colon has been described. The external burns are very variable and are seen on arcing side. Two cases [28] of lightning injury which occurred while mountain climbing. One case with lightning marks on the abdomen was treated as a crush injury because of myoglobinuria and elevation of serum glutamic oxaloacetic transaminase, lactic dehydrogenase and creatine phosphokinase. The other case had lightning burns and complained of abdominal pain. He was treated with fluid transfusion resulting from superficial and deep dermal burns estimated at 55% of the body surface and received a skin graft. The subsequent three-year follow-up has revealed no residual deformity in either case.

High-voltage injuries have been reported to cause other visceral injuries such as necrosis of the liver, pancreas, intestines, and gall bladder and coagulopathies. In lightning, the hepatic cells showed cyto-plasmic vacuolization occurring mainly between the nucleus and the sinusoidal border due to change in the electrical resistance of the plasma membrane induced by current. If the lightning area is very extensive, shock and secondary hypoxemic liver and kidney changes can be seen as in this case. Lightning injuries can also cause necrosis of the liver, pancreas, intestines, gall bladder, and coagulopathies.[15] Blast effect produces disruptive injuries in the internal organs.

4. Conclusion

During thunderstorm shelter near poles, trees are not safe for taking shelter. The safest shelter is close buildings, closed automobile, cave, lying on ground with curled up hands together, can be protective in compelling circumstances. Approximately one-third of lightning strikes are fatal.[1] Lightning injuries cannot be other than accident and with careful examination at experienced hands pose no difficulty in diagnosis.[29] The microscopic changes should be interpreted with other findings of the case as any high-voltage current and its heat can produce such findings. In this case, microscopic features of lightning injuries [Photographs 8–16] are contributed and reiterated as these are because of high-voltage current with additional effect of heat. Less intense voltage in the interior organs caused heat, coagulation, and resulted in ruptures of the vessels and caused almost infractions of heart, kidney and spleen. In this case, direct viewing of macroscopic as well as microscopic lightning injuries proves its worth for reading and recording. The most serious injuries are those affecting the cardiovascular, respiratory and neurological systems.[30] However, this case showed injuries in all systems of the body. It was an accidental death and did not pose any difficulty in identification. Lightning is a weather-related cause of injury and death here. The photographs are definitely a good addition to the existing literature of the subject.

Conflict of interest statement

There is no conflict to declare.

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Ethical Approval

No ethical approval is needed.

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